IOSR Journal of Environmental Science, Toxicology and Food Technology (IOSR-JESTFT)
e-ISSN: 2319-2402,p- ISSN: 2319-2399.Volume 16, Issue 4 Ser. I (April 2022), PP 29-37
www.iosrjournals.org

A Preliminary Study of Algal Biodiversity in Al Wathba Wetland Reserve Lake, Abu Dhabi, UAE

Anitha Saji[1]*, Rukhsana Kokkadan[2], Zamzam Salem Al Rashdi1, Pritpal S. Soorae1 & Shaikha Salem Al Dhaheri1
**Corresponding Author: asaji@ead.gov.ae*
1(Environment Agency - Abu Dhabi (EAD), United Arab Emirate).
2(Rukhsana: rukhsanaktkl@gmail.com, Nautica Environmental Associates LLC, Abu Dhabi, UAE).

Abstract
The current study is the first algal investigation into freshwater algae and cyanobacteria at the Al Wathba Wetland Reserve Lake (AWWR) in Abu Dhabi, United Arab Emirates (UAE). The emphasis was on cyanobacteria since knowledge on the biodiversity of freshwater species of green algae is fragmentary. The main aim of this study was to contribute to the species list of green algae and cyanobacteria from the lake as well as to evaluate species richness of algae and cyanobacteria. There were seven water samples/mats from four different sampling locations collected for the study which includes surface and bottom samples for the sites having more depth during the summer, on 29th June 2021. Algal and cyanobacterial taxa were determined according to morphological characteristics. Frequencies of individual taxa occurrence in samples were evaluated. Species richness differences between sampling sites was found. Dominating taxa differed between collection sites as well. There were nine species of algae and cyanobacteria observed from two phyla from seven sites in the AWWR Lake, Abu Dhabi, UAE. Algal flora, dominated by Phylum Ochrophyta was represented by 7 species identified (17.4 % of the total), 2 species of cyanobacteria with (82.6 %). A total of nine algal species were partially identified from the Phylum Ochrophyta with species such as Bacteriastrum delicatulum, Chaetoceros compressus, Amphora sp., Thalassiosira sp., Pleurosigma sp., Thalassionema nitzschioides and Nitzschia sp. and the Cyanobacteria species includes Trichodesmium erythraeum and Trichodesmium sp.
Keywords: *freshwater algae; diversity; ecology; bioindicator; water quality; protected area, Al Wathba Wetland Reserve Lake*

Date of Submission: 02-04-2022 Date of Acceptance: 15-04-2022

I. Introduction

One of the key wetlands in UAE, the Al Wathba wetland, is protected in an area known as the Al Wathba Wetland Reserve, which was the first protected area declared by Royal Decree in the Emirate of Abu Dhabi in 1998. The Environment Agency – Abu Dhabi (EAD) has managed AWWR since 1998 and it was recognised as a wetland of international importance under the Ramsar Convention on wetlands on 24th April 2013, becoming the first Ramsar site in the Emirate of Abu Dhabi, UAE (Ramsar Sites Information Service, 2013). In 2018, the wetland was listed in the IUCN Green List of Protected and Conserved Areas (UNEP-WCMC, 2018).

The biodiversity richness of this reserve is represented by 61 % of Abu Dhabi Emirate's bird species, 30 % of Abu Dhabi Emirate's reptile and amphibian species, 20 % of Abu Dhabi Emirate's mammal species, 16 % of Abu Dhabi Emirate's invertebrate species and 9 % of Abu Dhabi Emirate's plant species respectively (Soorae *et al*., 2020).

The diversity of the benthic algal flora is greater in the southern Gulf (Arabian coast) with about 130 species in common to the Iranian and Arabian side (John & Al-Thani, 2014). Algae are a large and diverse group of simple, photosynthetic, unicellular, and multicellular organisms. Algae are a major source of food for aquatic organisms and play an important role in the aquatic food chain or food web (Galloway *et al*., 2012). Algae contain photosynthetic pigments and use sunlight to produce food and oxygen from carbon dioxide and the water and are autotrophic in nature (Jha & Zi-rong, 2004). Seaweeds or algae are generally classified as rhodophyta (red algae), phaeophyta (brown algae) or chlorophyta (green algae) depending on their nutrient, pigments, and chemical composition. They are a valuable food resource, low in which contains low calories, and rich in vitamins, minerals, proteins, polysaccharides, steroids, and dietary fibres. As early as 3000 BCE, they were also considered important as traditional remedies (Lanora *et al*., 2006). In recent years, algae flourished in water polluted with organic wastes playing an important part in "self-purification of water bodies". Algae have become significant organisms for biological purification of wastewater as they are able to accumulate plant nutrients, heavy metals, pesticides,

Classification: Confidential - سري

organic and inorganic toxic substances, and radioactive matters in their cells/bodies (Alp *et al*., 2021; MacKenthun, 1969).

Algae are also known to be comparatively sensitive to chemicals. Their ecological position at the base of the aquatic food chain and their essential roles in nitrogen and phosphorus cycling are critical to aquatic ecosystems (Kalesh & Nair, 2005). Bio-indicator organisms can be used to identify and qualify the effects of pollutants on the environment and their period of persistence. Approximately 46 taxa have been announced as representatives of the clean water algae. The ecosystem approach to water quality assessment also includes diatom species, several flagellates and certain green and blue-green algae.

Algae are also able to accumulate highly toxic substances such as selenium, zinc and arsenic in their cells and/or bodies thus eliminating such substances from aquatic environments. Considering all these abilities of algae to purify the polluted waters of many types, it is worth to emphasize that algal technology in wastewater treatment systems is expected to get even more common in future years. Thus, an approach was undertaken to study the algal diversity in the freshwater bodies in Al Wathba Wetland Reserve Lake owing to their great biological activities.

II. Materials And Methods

Sampling sites description

Locations of four sampling sites are indicated in Figure 1. The Al Wathba Wetland Reserve (AWWR) Lake is located on the coastal sabkha plain *ca*. 40 km southeast of Abu Dhabi Island (Fig. 1). The partly dune-covered sabkha in the lake area lies 15–18 m above sea level. The region represented a seasonally flooded wetland with temporarily rising water levels probably resulting from increasing sub-surface water flow and hydrostatic pressure from stronger winds and higher tides in winter (Al Dhaheri, 2004). The construction of the Mussafah - Al Ain Truck Road between 1980 and 1984 dammed the southward flow of surface waters and increased the area and annual duration of emerging surface waters, and the abundance of waterfowl. The ecological potential of the wetland for local birdlife was recognised and AWWR Lake established as a perennial water body mostly fed by treated wastewater from the Mafraq Wastewater Treatment Plant, which is the main sewage treatment plant of the city of Abu Dhabi (Fig. 2). The permanent water body attracts a diverse birdlife and became protected as Al Wathba Wetland Reserve since 1998 due to the first successful breeding of the Greater Flamingo (*Phoenicopterus roseus*) on the Arabian Peninsula since a last record in 1922 from Kuwait (Ticehurst, 1926). A twenty-year biodiversity assessment and monitoring programme has documented a total of 354 invertebrate species, 16 reptile and amphibian species, 262 bird species, 10 mammalian species, and 39 plant species (Soorae *et al*., 2020). The protected wetland has an area of *ca*. 5 km² and the lake surface covers *ca*. 1.6 km² (Al Dhaheri, 2004). The maximum water depth of the lake is 2.3 m.

Classification: Confidential - سري

(Fig. 1). Locations of four sampling sites are indicated in AWWR Lake.

The AWWR is managed by the Environment Agency - Abu Dhabi (EAD) and mainly used for research, education and eco-tourism including birdwatching. The salinity of AWWR Lake is variable due to the freshwater input and the underlying sabkha substrate. However, most of the lake is hypersaline with a mean salinity of *ca*. 200 ‰ between 2010 and 2014 (Saji *et al*., 2016). During the same period, mean monthly values of water temperature, pH and dissolved oxygen concentration ranged from 22.8–35.9 °C, 7.0–8.6, and 3.7–7.9 mg L^{-1}, respectively (Saji *et al*., 2016).

Sampling, Preparation and Analysis

Phytoplankton

The communities of freshwater algae and cyanobacteria were sampled in the AWWR lake during the summer season. The collections were done during the water quality and brine shrimp monitoring programme of the month of June 2021. All samples were collected at water temperature of 31–35 °C. Thus, the mats of algae and cyanobacteria exhibited physiological activity. Mat samples were collected into polyethylene vials of 100 ml volume with a sufficient amount of ambient water and were then stored at a temperature of 4 °C in a refrigerator.

Optical Microscopy

Mat samples were analysed by an optical microscopy (Am Scope, Microscope Digital Camera, 18MP APTINA COLOUR CMOS) and digital photograph of the species forming the mat were taken (Biological Microscope, BS200). Throughout all samples, photographs were taken and analysed, so that individual mat forming species could be distinguished. A morphologic approach was used to determine particular algal and cyanobacterial species. Relative frequencies of species were calculated for each sample.

The sample container was inverted 30 times, and then passed over a vortex mixer for 30 seconds to remove the formation of aggregates and to mix the sample. A sub-sample of 100 µl was removed from the midpoint of the sample container using a 1000 µl micropipette. The sample was then pipetted into a ready-prepared Sedgewick rafter with a scale sheet for enumeration. However, the presence of phytoplanktonic organisms was not detected in the sub-sample of 100 µl. Full samples were then filtered through a 20 µm mesh and backwashed into a beaker. A wash bottle was used to make sure that no specimens were left in the mesh. The filtered sample was then pipetted into a ready-prepared Sedgewick rafter with a scale sheet for analysis and enumeration under the microscope.

Classification: Confidential - سري

The mesh was washed thoroughly after each sample to prevent cross contamination of specimens. The specimens of algal species were identified with the help of authentic literature up to species level or even up to variety level (Hustedt, 1930; Majeed, 1935; Smith, 1950; Presscot, 1962; Tilden, 1910).

III Results

A total of nine individual phytoplankton species were identified from the five samples collected, spanning two different taxa and two phyla. The Phylum Ochrophyta with species such as *Bacteriastrum delicatulum*, *Chaetoceros compressus*, *Amphora* sp., *Thalassiosira* sp., *Pleurosigma* sp., *Thalassionema nitzschioides* and *Nitzschia* sp. and the Cyanobacteria species includes *Trichodesmium erythraeum* and *Trichodesmium* sp. Phylum Ochrophyta represents most of the phytoplankton species, accounting for 17.40 %. Other remaining phylum Cyanobacteria accounted for 82.60 % respectively. Table 1. shows a taxonomic breakdown of the results separated by phylum. A full taxonomic breakdown of the results is provided in **Annexure A**.

Phylum	Phytoplankton cells per mL							Total	Percentage (%)
	Dragon Fly SITE	ST 05	ST 07-SF	ST 07-BT	ST 08-SF1	ST 08-SF2	ST 08-BT		
Ochrophyta	0	181	5 438	584	1	2 361	1	8 566	17.40
Cyanobacteria	1	26 231	13 360	865	102	0	102	40 661	82.60
Total phytoplankton	1	26 412	18 798	1 449	103	2 361	103	49 227	100.00

Table 1. Shows a taxonomic breakdown of the results separated by phylum.

Phylum	Class	Order	Family	Genus / Species	Phytoplankton cells per mL							Total
					DF SITE	ST 05	ST 07-SF	ST 07-BT	ST 08-SF1	ST 08-SF2	ST 08-BT	
Ochrophyta		Chaetoceratales	Chaetocerotaceae	*Bacteriastrum delicatulum*	0	0	0	0	0	2 140	0	2 140
				Chaetoceros compressus	0	0	0	0	0	4	0	4
		Thalassiophysales	Catenulaceae	*Amphora sp.*	0	0	0	0	0	8	0	8
		Thalassiosirales	Thalassiosiraceae	*Thalassiosira sp.*	0	42	0	0	0	48	0	90
			Pleurosigmataceae	*Pleurosigma sp.*	0	139	1	19	1	160	1	321
		Thalassionematales	Thalassionemataceae	*Thalassionema nitzschioides*	0	0	0	0	0	1	0	1
		Bacillariales	Bacillariaceae	*Nitzschia* sp.	0	0	5 437	565	0	0	0	6 002
Cyanobacteria	Cyanophyceae	Oscillatoriales	Phormidiaceae	*Trichodesmium erythraeum*	1	0	0	0	0	0	0	1
				Trichodesmium sp.	0	26 231	13 360	865	102	0	102	40 660
Total number of individual phytoplankton					1	26 412	18 798	1 449	103	2 361	103	49 227
Total number of taxa per sample					1	3	3	3	2	6	2	
Sample percentage per total					0.0020	53.65	38.19	2.94	0.21	4.80	0.21	100.00

Annexure A. A full taxonomic breakdown of the results is provided in

The most abundant phytoplankton cells per mL with a total count of Cyanobacteria with 40 661 comprised of ST 05 counted with 26 231; ST 07-BT with 13 360; ST 07-BT with 865; ST08-SF1 and ST08-BT with 102; DF SITE with 1 and ST08 F2 with 0 counts abundant, recording a total of 2 species individuals in taxa, accounting for 82.60 % of the total recorded phytoplankton. In contrast, less abundant Sample ST-07 SF had the less abundant phytoplankton cells per mL with a total count of Ochrophyta recorded 8 566 comprised of 5 438 in ST 07-SF; ST 08-SF2 with 2 361; ST07-BT 584; ST05 with 181; ST08-SF1 and ST 08-BT with 1 and 0 individuals in the DF SITE accounting for 17.40 % of the total recorded phytoplankton. The most abundance of Cyanobacteria recorded from ST 05 and Ochrophyta recorded from ST 07-SF. Figure 2 shows a graphical representation of the abundance of phytoplankton, separated by phyla. Figure 2 presents the percent composition of each phylum encountered within all the samples.

The species of *Bacteriastrum delicatulum*- is present in ST 08-SF2, *Chaetoceros compressus* in ST 08-SF2, *Amphora* sp in ST 08-SF2, *Thalassiosira* sp in ST 08-SF2 and ST 05, *Pleurosigma* sp. - ST 08-SF2, ST 05, ST 07-SF, ST 07-BT, ST 08-SF1, ST 08-BT, *Thalassionema nitzschioides* in ST 08-SF2, *Nitzschia* sp in the sites ST 07-SFand ST 07-BT, *Trichodesmium erythraeum* in DF SITE and *Trichodesmium* sp in the samples of sites

Classification: Confidential - سري

ST 08-BT, ST 05, ST 07-SF, ST 07-BT, ST 08-SF1. Photographs of phytoplankton species found in the analysed water samples are in the Plate: Figures 5. A-F.

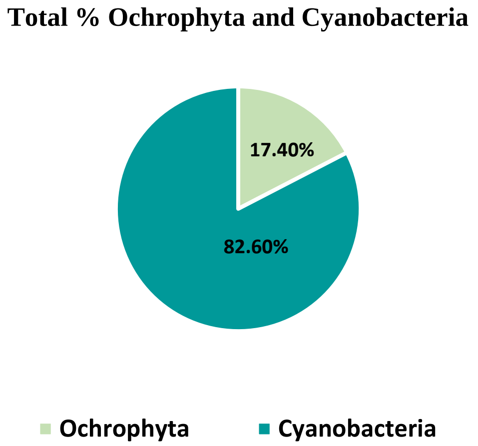

Figure 2. Presents the percentage composition of each phylum encountered within all the samples.

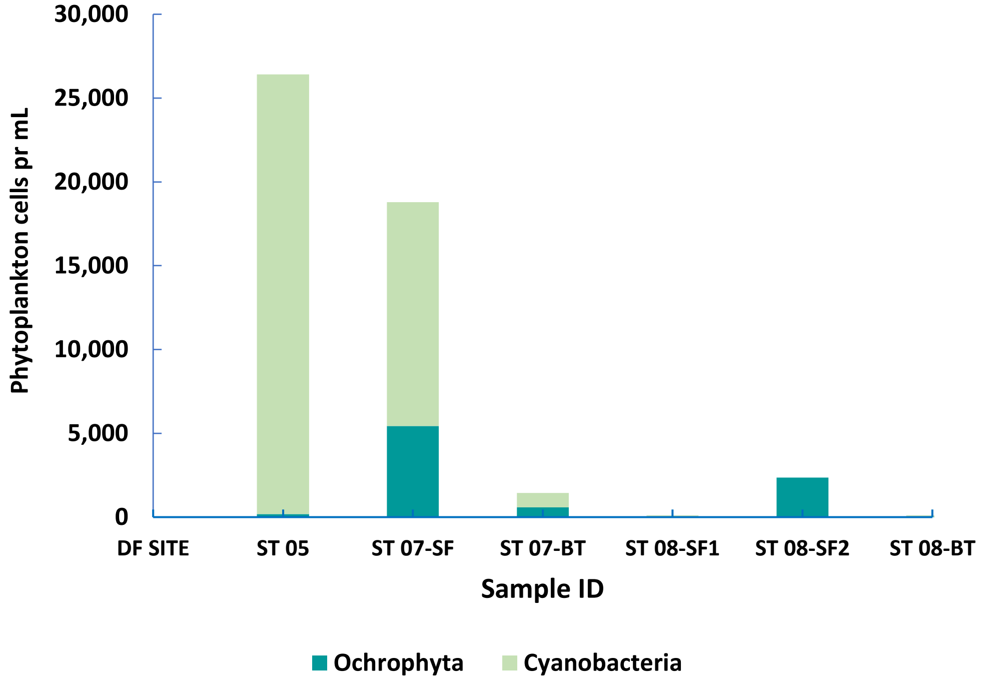

Figure 3. Shows a graphical representation of the abundance of phytoplankton, separated by phyla.

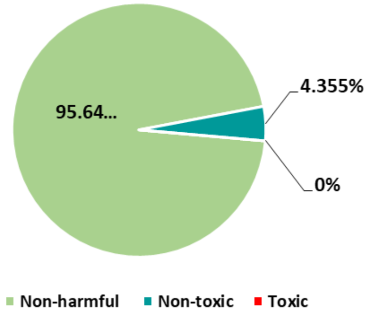

Figure. 4. Presents presenting the total Percentage of Non-harmful, Non-toxic and Toxic Algae in AWWR.

Classification: Confidential - سري

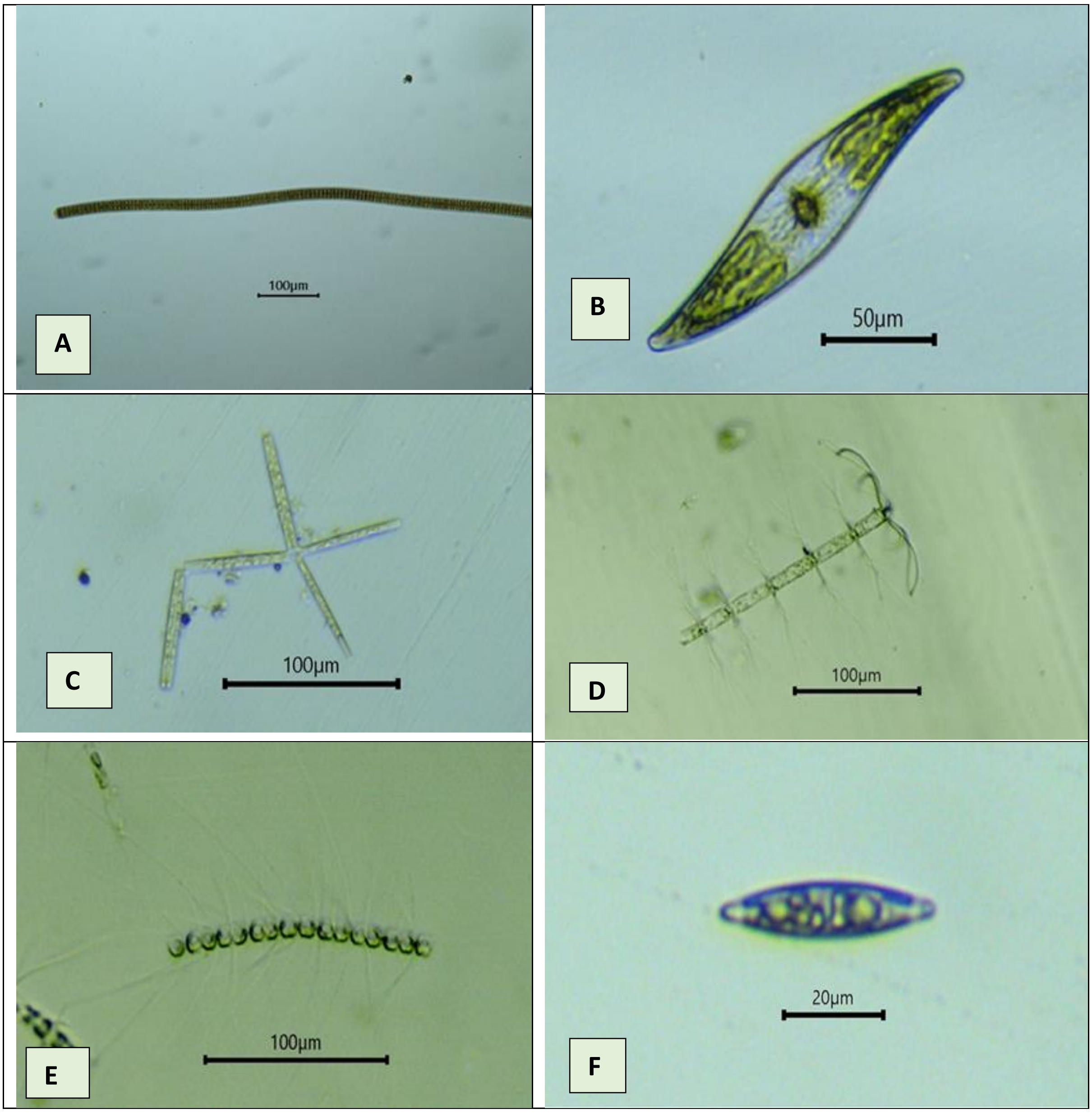

Figure. 5. Microscopic Algae from Al Wathba Lake. A – *Trichodesmium erythraeum*, B – *Pleurosigma* sp., C – *Thalassionema nitzchioides*, D – *Bacteriastrum delicatulum*., E – *Chaetoceros compressus*, F – *Nitzschia* sp.

III. Discussion

Freshwater habitats in the United Arab Emirates are scarce and the knowledge of their ecology is even less. Some research has been done on indigenous (wadi) fish (Feulner, 1998, 2006; Feulner & Cunningham, 2006) and aquatic invertebrates (Burt, 2003). Some large branchiopods have been found in the UAE (Hornby, 1999; Al-Khalili & Thompson, 2003; Al Dhaheri & Saji, 2013; Saji *et al*., 2016). Even from the best studied freshwater site, Wadi Wurrayah, however, the plankton is unknown.

As far as is known, no studies exist on plankton of freshwater or other inland aquatic habitats in the UAE. Published plankton studies in the UAE are restricted to the marine environment, which is relatively well studied (Rao & Al-Yamani, 1998; Al Qubaisi, 2006; Rajan & Abdessalaam, 2008; Bauman *et al*., 2010; Al-Shehhi *et al*., 2012). A preliminary investigation of plankton organisms of fresh and brackish inland waters in the northern United Arab Emirates (Soesbergen, 2019). The study provides knowledge on plankton organisms found in some inland waters in the northern UAE. Plankton are free-living micro-organisms in the water column and consist of Phyto- and zooplankton. Important groups in the phytoplankton are cyanobacteria, green-algae and diatoms.

In Abu Dhabi Emirate, few algal studies have been conducted but little attention was given to explore algal flora of Al Wathba wetland reserve (Al Dhaheri, 2004). Our study in freshwater bodies showed diversity of algal species in which a total of nine individual phytoplankton species were identified from the five samples

Classification: Confidential - سري

collected, spanning two different taxa and two phyla. The Phylum Ochrophyta with species such as *Bacteriastrum delicatulum*, *Chaetoceros compressus*, *Amphora* sp., *Thalassiosira* sp., *Pleurosigma* sp., *Thalassionema nitzschioides* and *Nitzschia* sp. and the Cyanobacteria species includes *Trichodesmium erythraeum* and *Trichodesmium* sp.

Total number of nine algal and cyanobacterial taxa were found in seven samples from the material collected at four investigated sampling sites (see Fig. 1, Table 1). Biodiversity differed between sampling sites, however a large variation in species composition was found even within a single sample. The most abundant phytoplankton cells per mL with a total count of Cyanobacteria with 40 661 comprised of ST 05, Previous studies showed that species abundance varies with seasons and as some which appeared during spring and summer and disappeared in the autumn (Haq *et al*., 2012). Previously some research work has been carried out on the algal diversity variations in algal composition and diversity and it was found that it was varied at bottom, middle and surface layers of water due to formation of thermocline in water body. Bioindicator organisms indicate the effects of different pollutants in aquatic ecosystems. Phyto planktons are reliable tool to evaluate the water quality of wetlands (Crosseti *et al*., 2008). Freshwater bodies and lakes are characterised on the basis of dominant algal group. The dominance of green algae and diatoms indicate the oligotrophic conditions while abundance of blue green algae indicate the eutrophic conditions of water bodies (Musharaf *et al*., 2011). Our findings agree with Palmer (1969) and Musharaf *et al*. (2011).

Phylum Ochrophyta contained seven individual phytoplankton cells across taxa, accounting for 17.40 % of the total recorded phyla. Within the phylum, the most numerous species were *Nitzschia* sp (Bacillariales: Bacillariaceae) A total of 6 002 individuals were recorded of the previously mentioned species, which accounts for 12.19 % of the total recorded taxa. All the taxa present within the phylum belong to the class Bacillariophyceae.

Bacillariophyceae, commonly referred to as diatoms, are unicellular eukaryotic algae found in almost every aquatic environment. They are a significant component of phytoplanktonic communities throughout the world, with some estimates suggesting that they may account for as much as 20 % of global carbon fixation per year (Raymont, 1983).

Phylum Cyanobacteria was the most abundant phylum within the samples, a species of *Trichodesmium erythreum* (Plate 1. Fig. A) represents the phylum. A total of one individual, accounting for 0.002 % of the total recorded phytoplankton within the samples. *Trichodesmium* species are visible to the naked eye and are also known as “sea sawdust”. *Trichodesmium* sp. colonies can be yellowish-brown to deep red in colour due to their primary light-harvesting pigment, phycoerythrin. They move vertically through the water column and are buoyant to be able to regulate their position in the water column due to large gas-filled vacuoles or vesicles in each cell. Members of the genus *Trichodesmium* spp. fix N_2 exclusively in the light (Dugdale *et al*., 1961; Capone *et al*., 1997).

Phytoplankton is characterised by short life spans and fast turnover periods. This enables phytoplankton communities to take advantage of favourable conditions within the environment, reaching community densities where they are described as a bloom. These blooms are dynamic, appearing suddenly and lasting a few days or weeks. The community structure within a bloom shift according to changes within the environment, resulting in changes to the dominant phytoplankton species. While not all phytoplankton blooms (sometimes termed 'red tides') are harmful, the type of phytoplankton in dominance and the nature of the environment may result in the formation of a Harmful Algal Bloom (HAB). Some phytoplankton produces toxins implicated in the deaths of fish and marine mammals, where bioaccumulation causes the toxins to increase in concentration as they move up the food chain, posing a threat to humans. Some of the recorded species were classed as non-toxic on the IOC-UNESCO HAB database. However, Figure 4 details many species listed as being potentially and indirectly harmful and which were found in the samples analysed. Indirectly harmful species were classified as such, as they do not produce toxins, but can have significant detrimental effects on other organisms. Figure 4. presents the percentages of toxic, non-toxic, and non-harmful phytoplankton species recorded within the analysed samples. The toxic accounts for 0 % and non-toxic species account for 4.35 % and non-harmful phytoplankton by 95.64 % respectively.

Results showed dominance of a non-toxic species Cyanobacteria accounted for 4.35 % respectively which makes up around 82.6 % of cell counts. Although taxa categorised as “non-toxic” are not directly known to produce toxins, they can still impose risks, specifically, potentially creating hypoxic or even anoxic conditions when in high concentrations. Other species categorised as non-toxic organisms found in smaller quantities include the one individual of *Trichodesmium erythraeum*, 40 660 individuals of *Trichodesmium* sp.

IV. Conclusions

Algal and cyanobacterial communities forming a mat of the AWWR lake consist of at least nine species. Therefore, it can be ranked as a complex and species-rich microbial community. In conclusion, the biodiversity of algal and cyanobacterial species in majority of the studied sites might be higher than reported in this study, because some species have not yet been determined (see Fig. B & F). Furthermore, future sampling of the sites at

Classification: Confidential - سري

the AWWR lake will undoubtedly bring new species because there are numerous wet ecosystems varying in ecological conditions. This is promising for future studies on biodiversity of algae and cyanobacteria in AWWR Lake. Recently, microorganisms from extreme environments, including Polar Regions (Fernández- Valiente *et al*., 2007), represent a great potential for biotechnology since they may be used as a source of secondary compounds that exhibit biological activity. The majority of observed algal and cyanobacteria diversity was represented by autotrophic species. This reflects the community high self-purification capacity, which is very important for the protection regime control but could not be revealed with chemical analysis only.

They are considered as a source of bioactive compounds as they are able to produce a great variety of secondary metabolites and a valuable food resource too. Some of the algae have also been known to be pollution indicator and helps in reduction of industrial pollutants in small lakes and other water sources. With the above contribution of algae, an attempt was made to diversify the algae species that are in AWWR and document the presence of valuable algal species.

AWWR lake differ in a biodiversity of their benthic mats. Some could be monospecific, formed typically by a single cyanobacterium, the others could be formed by several dominant species (Singh & Elster, 2007). Algal and cyanobacterial communities forming a mat of the AWWR lake might consist of more than 2 species. In conclusion, the biodiversity of algal and cyanobacterial species in majority of the studied sites might be higher than reported in this study, because some species have not yet been determined (see Fig. B, F). Furthermore, future sampling of the sites at the freshwater bodies in the Emirate will undoubtedly bring new species because there are numerous wet ecosystems varying in ecological conditions. A priority for future research is to perform further basic freshwater surveys to fill the many gaps in our knowledge of benthic algal diversity within the Abu Dhabi Emirate, with special attention directed towards under collected areas where suitable habitats exist.

Acknowledgments

Our thanks are due to Mr Veryan Pappin (Nautica Environmental Associates LLC, Abu Dhabi, UAE) for his permission to use his laboratory facilities for this study. We thank Sirthaj Khan, for his efforts to assist the water sampling from the study sites in the lake. The authors are very grateful to the EAD research and technical committee for their review and comments on the manuscript. The study was supported by Environment Agency - Abu Dhabi (EAD).

References

[1]. Al Dhaheri, S. 2004. Assessment of Brine Shrimp (Artemia sp.) productivity at Al Wathba Wetland Reserve, Abu Dhabi, UAE. M.Sc. Thesis, University, Al Ain, UAE.
[2]. Al Dhaheri, S. & A. Saji 2013. Water quality and brine shrimp (Artemia sp.) population in Al Wathba Lake, Al Wathba Wetland Reserve, Abu Dhabi Emirate, UAE. International Journal of Biodiversity and Conservation 5(5): 281–288.
[3]. Alp, M.T. et al., 2012. Determination of heavy metals in sediment and macroalgae on the. Mersin coast. Ekol 21 (82), 47–55. Al Qubaisi, S. and Salem, B. 2006. "A Study of Factors Influencing the Occurrence of Algae Bloom (HAB) Along the Abu Dhabi Coast, UAE." Thesis. 565.
[4]. Al-Khalili, Y. & Thompson, K. 2003. First records of the Tadpole Shrimp Triops cancriformis (Bosc. 1801) (Crustacea: Branciopoda: Notostraca: Triopsidae) from the UAE. Tribulus 13(2): 11–13.
[5]. Al-Shehhi, M.R., Gherboudj, I. and Ghedira, H., 2012. Temporal-spatial analysis of chlorophyll concentration associated with dust and wind characteristics in the Arabian Gulf. In 2012 Oceans-Yeosu (pp. 1-6). IEEE.
[6]. Bauman, A.G., John A. B., David A. F., Marquis, E., Usseglio, P. 2010. Tropical harmful algal blooms: An emerging threat to coral reef communities? Marine Pollution Bulletin, Volume 60, Issue 11, 2010, Pages 2117─2122.
[7]. Burt, J. 2003. Aquatic invertebrates of an intermittent stream in the arid Hajar Mountains. Tribulus 13(2): 14–22.
[8]. Capone, D.G., Zehr, J.P., Paerl, H.W., Bergman, B. and Carpenter, E.J., 1997. Trichodesmium, a globally significant marine cyanobacterium. Science, 276(5316), pp.1221─1229.
[9]. Crosseti, L. et al., 2008. Structural and functional phytoplanktons responses to nutrient. Impoverishment in mesocosms placed in shallow eutrophic reservoir, Sao Paulo. Brazil. Hydrobio 541, 71–85.
[10]. Dugdale, R.C., 1961. Nitrogen fixation in the Sargasso Sea. Deep-Sea Res., 7, pp.298─300.
[11]. Feulner, Gary & Cunningham, Peter. (2000). The freshwater goby Awaous aeneofuscus in the Wadi Hatta watershed (U.A.E./Oman). Feulner, G.R. and Cunningham, P.L. (2000) Tribulus 10.1: 12-15. Available online via: http://www.enhg.org/Portals/1/trib/V10N1/TribulusV10N1Searchable.pdf. 10. 12 - 15.
[12]. Feulner, G.R. 1998. Wadi fish of the UAE. Tribulus 8 (2): 16–22.
[13]. Feulner, G.R. 2006. Goby gone for good. Tribulus 16 (2): 34.
[14]. Fernandez-Valiente E, Camacho A, Rochera C, Rico E, Vincent WF, Quesada A (2007) Community structure and physiological characterization of microbial mats in Byers Peninsula, Livingston Island (South Shetland Islands, Antarctica). FEMS Microbiol Ecol 59:377–385.
[15]. Galloway, A.W. et al. 2012. Fatty acid signatures differentiate. marine macrophytes at ordinal and family ranks. Phycol 48, 95–965. Hatta watershed (U.A.E/Oman). Tribulus 10(1): 12–15.
[16]. Haq, U.W. et al., 2012. Taxanomic study of some Cosmarium Jehlum River, Azad. Kashmir. J of Draing and Water Manage 6 (2):33–48.
[17]. Hornby, R. J. 1999. Clam shrimps (Branciopoda, Crustacea) – a new discovery for the UAE. Tribulus 9(1):16–17.
[18]. Hustedt, F. 1930. Bacillariophyta (Diatomeae). Fisher Verlag Jena Pp 466. Jang, N.S., Zahir, S. Jan, Junaid, S., Khan, A., et al., 2014. Local screening for Algal diversity in relation t0. water quality of district Swabi: future prospects. J. of Biodiv and Envi Sci 5 (3), 9–13.

Classification: Confidential - سري

[19]. Jha, Rajeev & Xu, Zi-Rong. (2004). Biomedical Compounds from Marine organisms. Marine Drugs. 2. 10.3390/md203123.
[20]. John, D. & Al-Thani, R. 2014. Benthic marine algae of the Arabian Gulf: a critical review and analysis of distribution and diversity patterns. Nova Hedwigia. 98. 10.1127/0029-5035/2014/0156.
[21]. Kalesh, N.S. and Nair, S.M. 2005. "The accumulation levels of heavy metals (Ni, Cr, Sr, & Ag) in marine algae from Southwest Coast of India" Toxicological & Env Chem, 87: 2, 135-146., 2005.
[22]. Lanora, A., Boersma, M., Casotti, R., Fontana, A., Harder, J., Hoffmann, F., Pavia, H., Potin, P., Poulet, S.A. and Toth, G. 2006. "New trends in marine chemical ecology", Estuaries Coasts, 29, 531–551.
[23]. MacKenthun, K.M. 1969. "Radioactive wastes". Chapter 8. İn the practice of water pollution biology. U.S. Dept. Interior, Fed. Water Pol. Contr. Admin., Div. of Tech. Support. U.S. Printing Office., 1969.
[24]. Majeed, A.M. 1935. Fresh water algae of Punjab part I Bacillariophyta (Diatomae). Pak. J. Bot. 41 (5), 2551–2561.
[25]. Musharaf, K., Farrukh, H., Shahana, M., 2011. A fraction of freshwater Algae of Kalpani stream and Adjoining area of District Mardan, Pakistan. Int. J. Biosci. 145–150.
[26]. Palmer, C.M., 1969. Composite rating of algae tolerating organic pollution. J. Phycol 5, 78–82.
[27]. Presscot, G.W., 1962. Algae of western great lakes area. C. Brown Co., Dusuoue, lowa, W.M, p. 970.
[28]. Rajan, A. & Abdessalaam, T.Z. 2008. Guide to common marine phytoplankton in Abu Dhabi waters. Environment Agency – Abu Dhabi.
[29]. Ramsar Sites Information Service. 2013. Al Wathba Wetland Reserve https://rsis.ramsar.org/ris/2142
[30]. Rao, S., & Al-Yamani, F. 1998. Phytoplankton ecology in the waters between Shatt Al-Arab and Straits of Hormuz, Arabian Gulf: A review. Plankton Biology and Ecology, 45(2), 101-116.
[31]. Raymont, J. E. G. 1983. Plankton and productivity in the oceans. Zooplankton, 2.
[32]. Saji, A., S. Al Dhaheri, J. N. Shah & P. S. Soorae. 2016. Influence of chemical parameters on Artemia sp. (Crustacea: Anostraca) population in Al Wathba Lake in the Abu Dhabi Emirate, UAE. International Journal of Aquatic Biology Karaj 4(2): 87–95.
[33]. Singh, S.M., Elster, J. 2007. Cyanobacteria in Antarctic Lake Environments. In: Seckbach J. (eds) Algae and Cyanobacteria in Extreme Environments. Cellular Origin, Life in Extreme Habitats and Astrobiology, vol 11. Springer, Dordrecht. https://doi.org/10.1007/978-1-4020-6112-7_16.
[34]. Smith, G.M. 1950. The Fresh-Water Algae of United States of America, McGraw Hill, New York, America.
[35]. Tiffany, LH, and ME, Britton (1971). The algae of Illinois. Hapner p Co 395.
[36]. Soesbergen, M. (2019). A preliminary investigation of plankton organisms of fresh and brackish inland waters in the northern United Arab Emirates. 26. 46–58.
[37]. Soorae, P., Sakkir, S., Saji, A. et al. (2020). A Review of the Flora and Fauna in the Al Wathba Wetland Reserve in Abu Dhabi, United Arab Emirates. Wetlands 40, 1505–1512. https://doi.org/10.1007/s13157-019-01235-x
[38]. Tilden, J., 1910. Minnesota algae. Minneapolis 1, 555. Vadlapudi, V., 2012. Antioxidant activities of marine algae. A review. Research signpost. 189–203.
[39]. Ticehurst, C.B. 1926. Additional notes on the avifauna of Iraq. Journal Bombay Natural History Society. 31:110.
[40]. UNEP-WCMC (2018). Protected Area Profile for Al Wathba from the World Database of Protected Areas December 2018. Available at: www.protectedplanet.net

Anitha Saji, et. al. "A Preliminary Study of Algal Biodiversity in Al Wathba Wetland Reserve Lake, Abu Dhabi, UAE." *IOSR Journal of Environmental Science, Toxicology and Food Technology (IOSR-JESTFT)*, 16(04), (2022): pp 29-37.

Classification: Confidential - سري